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The CORRUGATION METHOD OF IRRIGATION

THE CORRUGATION METHOD of irrigation is well adapted for the efficient application of water to steep or irregular slopes, or where the farmer is required to use a small stream of water, or for new land which has not yet been thoroughly prepared for irrigation. It may sometimes be used to advantage in conjunction with the border method of irrigation as a means of spreading the water evenly over the border strip. This bulletin describes the most approved practices to be followed when the corrugation method is employed and points out its advantages and limitations.

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THE CORRUGATION METHOD OF IRRIGATION.

By James C. Marr, *Irrigation Engineer, Division of Agricultural Engineering, Bureau of Public Roads.*

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INTRODUCTION.

The corrugation method of irrigation is a modification of the older and more widely known furrow method. It had its origin in the Northwestern States and is now generally used there in watering uncultivated crops such as small grains and hay. Some means of flooding the entire ground surface is usually employed elsewhere for the irrigation of such crops; but owing to the rough topography, peculiarities of soil, methods of planting and harvesting crops, and the established practice of using small streams of water for irrigating, the corrugation method has come into general favor in the Northwest.

The principle involved in the corrugation method is that of subirrigation accomplished by allowing small streams of water to flow through a series of narrow, shallow furrows or corrugations long enough to permit the horizontal seepage from adjacent irrigated corrugations to meet, thus resulting in a thorough wetting of the soil between the corrugations. Four general features of the method should be considered in planning for irrigation by means of corrugations, these being the field ditches, the structures, the corrugations themselves, and the wasteways.

FIELD DITCHES.

Field ditches are the portion of an irrigation canal system which supplies water to a single farm unit or field and for which the individual farmer is responsible. The term includes the farm supply ditch and head ditches, the latter being that part of the system from which water is turned on the land.

Owing to the limited head of water used, these field ditches are small and easily constructed. The general practice calls for the continuous use of from one one-hundredth to one-fiftieth cubic foot per second of water per acre of land irrigated during an irrigation season, which results in the use of a stream which rarely exceeds 2 cubic feet per second and averages considerably less. Such ditches are usually made by plowing and removing the loose dirt from the furrow with an ordinary "A" ditcher. This operation repeated several times, supplemented by a little handwork, completes the ditch.

Table 1 gives the different carrying capacities of two small ditches on various slopes. These ditches are of a size close enough to that ordinarily required to serve as a guide in the design of such ditches.

TABLE 1.—*Carrying capacities of field ditches.*

DITCHES 5 INCHES DEEP, 14 INCHES IN BOTTOM WIDTH, WITH 1½ TO 1 SIDE SLOPES, ON DIFFERENT GRADES.

Grade.			Mean velocity.	Carrying capacity.		
				Cubic feet per second.	Miners inches.	
					6-inch head.	4-inch head.
Inches per rod.	*Feet per 100 feet.*	*Feet per mile.*	*Feet per second.*			
¼	0.126	6.67	0.71	0.53	21	26
½	.252	13.33	1.01	.76	30	38
¾	.379	20.00	1.24	.93	37	47
1	.505	26.67	1.43	1.08	43	53
1¼	.631	33.34	1.60	1.20	48	60
1½	.758	40.00	1.76	1.32	53	66
1¾	.884	46.67	1.91	1.43	57	71
2	1.010	53.33	2.06	1.53	61	77
2½	1.263	66.67	2.29	1.71	68	85
DITCHES 6 INCHES DEEP, 16 INCHES IN BOTTOM WIDTH, WITH 1½ TO 1 SIDE SLOPES, ON DIFFERENT GRADES.						
¼	0.126	6.67	0.80	0.85	34	42
½	.252	13.33	1.17	1.22	49	61
¾	.379	20.00	1.41	1.50	60	75
1	.505	26.67	1.67	1.74	70	87
1¼	.631	33.34	1.87	1.95	78	98
1½	.758	40.00	2.05	2.13	85	106
1¾	.884	46.67	2.21	2.30	92	115
2	1.010	53.33	2.37	2.47	99	124
2½	1.263	66.67	2.66	2.77	111	139

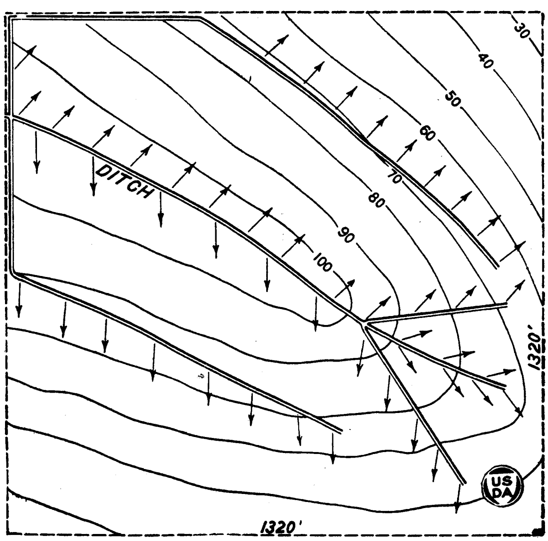

FIG. 1.—Characteristic field map showing location of contours and ditches.

Where the slope of the land is uniform and in one direction, the ditch system is quite simple. A supply ditch is run directly down the steepest slope and head ditches are located at right angles to it, or nearly so, on grades of from 0.05 to 0.25 per cent and at intervals of from 150 to 600 feet, depending upon the length of corrugation to be used.

Where the ground surface is uneven in character there is no general plan that will fit all conditions for laying out a system of farm ditches, but the water must be released at points on a field from which it may flow directly down the steepest slope, or nearly so, a requirement of the corrugation method which will be explained later. As long as this requirement is satisfied the grade need not be uniform, though a uniform slope between head ditches is to be preferred. A contour map upon which trial locations can be made will assist greatly in laying out a satisfactory system of field ditches. The elevations of a number of points must be determined to permit the

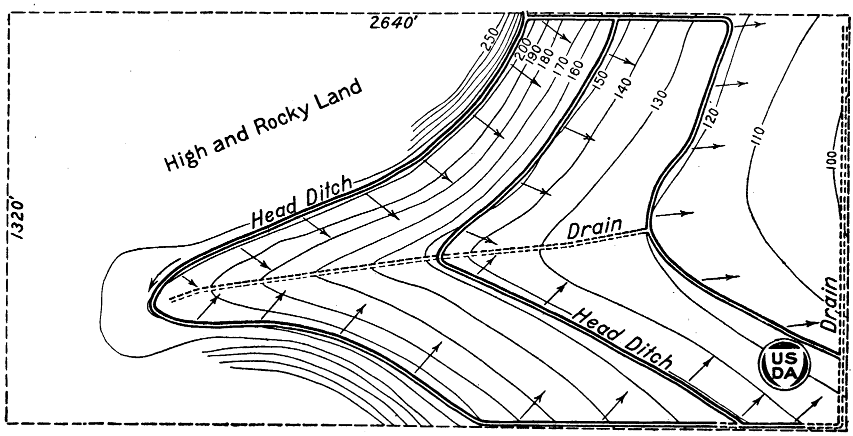

FIG. 2.—Field laid out with ditches on contours.

preparation of an accurate map of surface conditions. Especially where land is uneven this task is best left to a surveyor. Two typical irrigation systems are illustrated in Figures 1 and 2.

What has been said of the location of a system of field ditches for the corrugation method applies as well to a pipe-line distribution[1] system. However, because of their initial cost, such installations are usually limited to the irrigation of orchards and other highly profitable crops and can seldom be afforded for hay, small grains, and other crops raised under the corrugation method.

STRUCTURES.

Considering field ditches in the order of their usual construction and operation, the point of division, diversion, and measurement of water from larger streams should first receive attention. At this point water is usually admitted to a number of farm ditches through several head gates which are so regulated as to show the proper

[1] U. S. Dept. of Agr., Dept. Bul. 906, The Use of Concrete Pipe in Irrigation.

depth of water over a weir [2] located some distance below the gate. A standard head gate in general use in southern Idaho is shown in Figure 3. An accurate method of measuring water where streams diverted to farm ditches are so numerous and so small is very desirable, since it promotes a careful use of water and tends to reduce disputes and dissatisfaction regarding the quantity of water delivered. Under many canal systems no attempt is made to do more than divide the total quantity of water available among a number of users, and this is done only approximately by varying the width of outlet directly with the size of stream supposed to be diverted. The structure used for this purpose is known as a proportional division box. An example of such a structure is shown in Figure 4. Although proportional division boxes can be constructed and maintained so as to give satisfactory

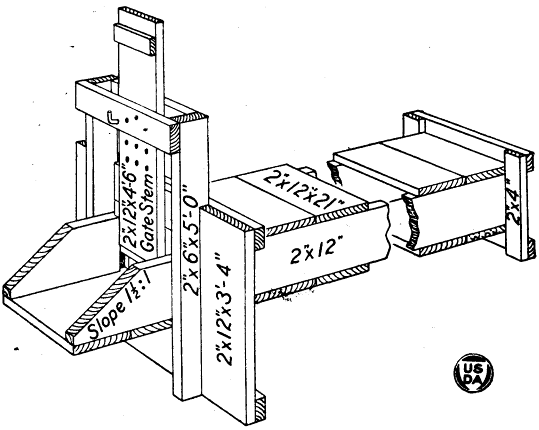

Fig. 3.—Standard wooden headgate used for delivery of small irrigating streams.

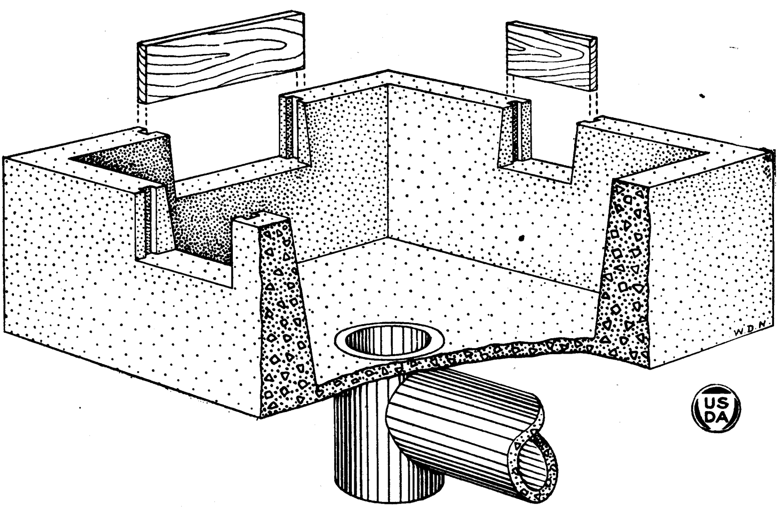

Fig. 4.—Proportional division box.

results, the fact is that they are not usually constructed and maintained with sufficient care and there is little to recommend their use.

When it is necessary to locate a ditch where the grade will be so steep as to cause erosion of an earthen channel miniature chutes are

[2] See U. S. Dept. of Agr., Farmer's Bulletin No. 813, Construction and Use of Farm Weirs.

used. To form these the ditch may be lined with concrete, but a wooden V-shaped trough made up of short planks laid one into the other on the ground, as illustrated in Figure 5, meets this requirement very successfully. Such an arrangement is not expensive and has the added advantage that it may be removed easily during farm operations, thus reducing the area of waste land.

In the irrigation of rolling, uneven land, the small farm flume is a necessary structure. It may be a home made rectangular affair built preferably of redwood, or it may be of the semicircular metal type which can be purchased. Flumes of either type are satisfactory if properly installed, but the homemade wooden flume is often carelessly built and poorly maintained and it then constitutes a weakness in the farm ditch system as well as a

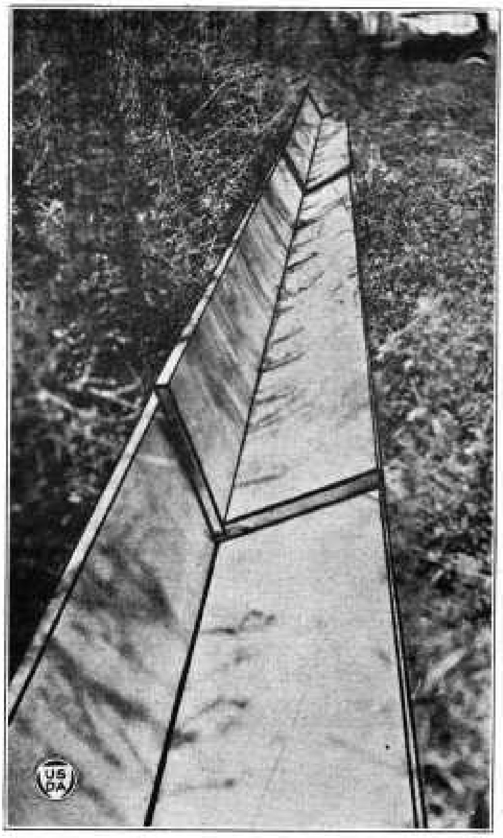

FIG. 5.—Wooden trough used to prevent soil erosion.

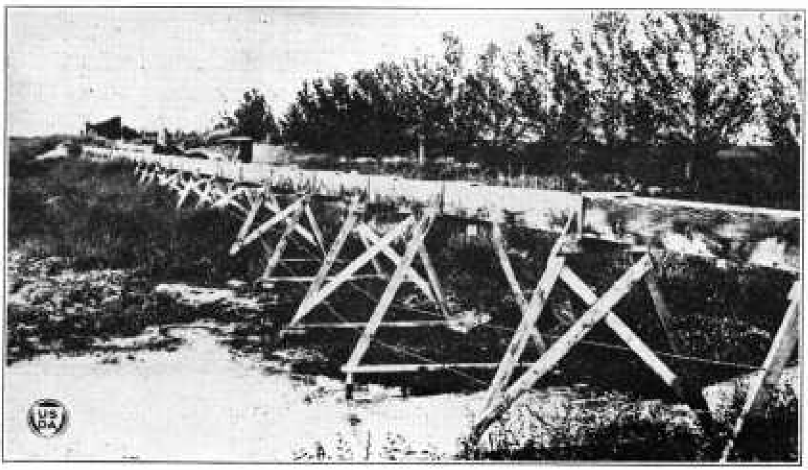

FIG. 6.—Well built wooden flume.

source of water waste. A substantially built and well-maintained wooden flume is shown in Figure 6; Figure 7 shows one in bad condition. Metal flumes are seldom so poorly constructed and cared for. A good semicircular flume is shown in Figure 8. It will be found that fre-

FIG. 7.—Poorly built wooden flume.

quent treatment of both metal and wooden flumes with a heavy asphaltic waterproof paint will add greatly to their life.

Tables 2 and 3 give the maximum carrying capacities of various sizes of small wooden and metal flumes laid on different slopes.

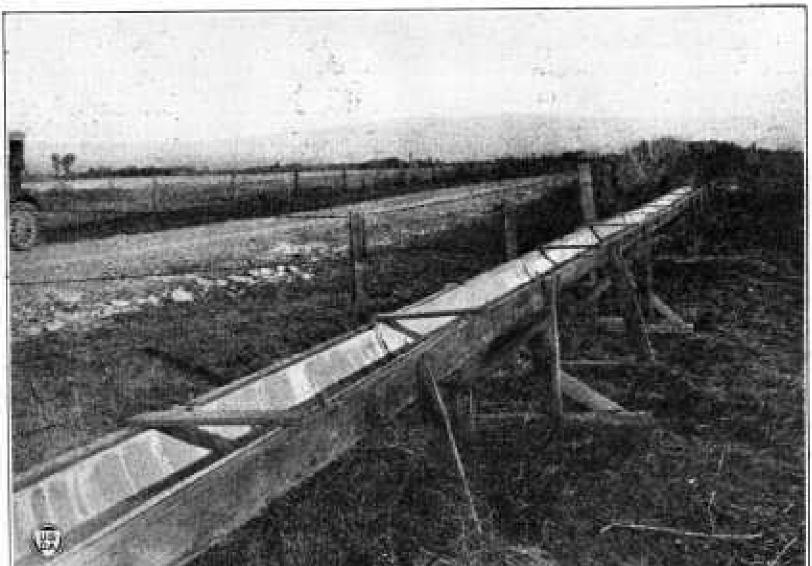

FIG. 8.—Small semi-circular metal flume.

Permanent structures of wood or concrete, similar to that shown in Figure 9, may be used for diverting the irrigation stream from the main supply ditch to head ditches. However, a movable canvas (Fig. 10) or metal dam (Fig. 11) is usually all that is necessary.

TABLE 2.—*Carrying capacities of small rectangular wooden flumes on different slopes when running full.*

Inside measurement.	Discharge.	Fall, in feet per 100 feet. 0.05	0.10	0.15	0.20	0.30	0.40	0.50	0.60	0.80
Inches.										
7 by 8	Cubic feet per second	.29	.41	.51	.60	.73	.85	.95	1.04	1.20
	Miner's inches, $\frac{1}{40}$ second-foot	11.6	16.4	20.4	24.0	29.2	34.0	38.0	41.6	48.0
	Miner's inches, $\frac{1}{50}$ second-foot	14.5	20.5	25.5	30.0	36.5	42.5	47.5	52.0	60.0
9 by 10	Cubic feet per second	.56	.81	.99	1.15	1.41	1.64	1.83	2.01	......
	Miner's inches $\frac{1}{40}$ second-foot	22.4	32.4	39.6	46.0	56.4	65.6	73.2	80.4	......
	Miner's inches $\frac{1}{50}$ second-foot	28.0	40.5	49.5	57.5	70.5	82.0	91.5	100.5	......
11 by 12	Cubic feet per second	.95	1.36	1.68	1.95	......	......	......	......	......
	Miner's inches $\frac{1}{40}$ second-foot	40.0	54.4	67.2	78.0	......	......	......	......	......
	Miner's inches $\frac{1}{50}$ second-foot	47.5	68.0	84.0	97.5	......	......	......	......	......

TABLE 3.—*Carrying capacities of small semicircular metal flumes on different slopes when running full.*

Inside diameter.	Discharge.	Fall, in feet per 100 feet. 0.05	0.10	0.15	0.20	0.30	0.40	0.50	0.60
Inches.									
	Cubic feet per second	.13	.19	.23	.26	.33	.38	.43	.47
7⅝	Miner's inches, $\frac{1}{40}$ second-foot	5.2	7.6	9.2	10.4	13.2	15.2	17.2	18.8
	Miner's inches, $\frac{1}{50}$ second-foot	6.5	9.5	11.5	13.0	16.5	19.0	21.5	23.5
	Cubic feet per second	.24	.34	.42	.49	.60	.71	......	......
9½	Miner's inches, $\frac{1}{40}$ second-foot	9.6	13.6	16.8	19.6	24.0	28.4	......	......
	Miner's inches, $\frac{1}{50}$ second-foot	12.0	17.0	21.0	24.5	30.0	35.5	......	......
	Cubic feet per second	.40	.58	.72	.84	1.02	......	......	......
11½	Miner's inches, $\frac{1}{40}$ second-foot	16.0	23.2	28.8	33.6	40.8	......	......	......
	Miner's inches, $\frac{1}{50}$ second-foot	20.0	29.0	36.0	42.0	51.0	......	......	......
	Cubic feet per second	.60	.86	1.06	1.23	......	......	......	......
13½	Miner's inches, $\frac{1}{40}$ second-foot	24.0	34.4	42.4	49.2	......	......	......	......
	Miner's inches, $\frac{1}{50}$ second-foot	30.0	43.0	53.0	61.5	......	......	......	......
	Cubic feet per second	1.19	1.70	......	......	......	......	......	......
17	Miner's inches, $\frac{1}{40}$ second-foot	47.6	68.0	......	......	......	......	......	......
	Miner's inches, $\frac{1}{50}$ second-foot	59.5	85.0	......	......	......	......	......	......

Probably the most important structures and those which are used more exclusively under the corrugation method of irrigation are to be found in the head ditch, where they are employed as a means of distributing a stream of water evenly among a number of corrugations. Structures such as checks, outlet and overflow boxes, and wooden spouts, and the head ditch itself must be capable, increasingly with the steepness of slope and looseness of soil, of delicate adjustment, so that irrigating streams in all corrugations may be regulated to deliver the proper amount during any absence of the irrigator. The system must be safeguarded to prevent the overflow or washing through of ditch banks which would result in the release of such streams as would damage fields and crops by flooding or erosion.

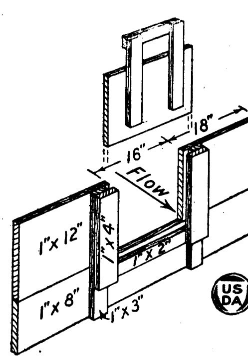

FIG. 9.—Permanent wooden check for use in small capacity field ditches.

Usually water is not allowed to flow directly into corrugations from the head ditch, but first enters distributing basins by outlets through the sides of the ditch. These distributing basins are long, narrow depressions about 2 feet wide at the water line and vary in

length from 20 to 60 feet, depending upon the head of water available and the slope of the field alongside the ditch. Unlike the ditch itself, the basin must be level, and a series of basins has the appearance of low, broad steps up the slope of a field. They must be so built as to permit the discharge of water to the field throughout the length of each basin. These basins are divided from each other by earthen dams, forming a series of small reservoirs, each of which has as its upper bank the lower side of the head ditch. The purpose of these distributing basins is to permit the regulation of a number of small streams as a unit and to allow a division of the main irrigating stream to be made among several basins, so that damage to field and crop may be reduced in case of a break in the banks of the distribution system. The use of the distributing basin is a wise precaution in the irrigation of new lands or loose soil or steep slopes; it is also of assistance in the equal division of water among a

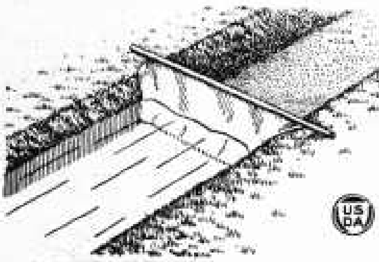

FIG. 10.—Portable canvas dam in ditch.

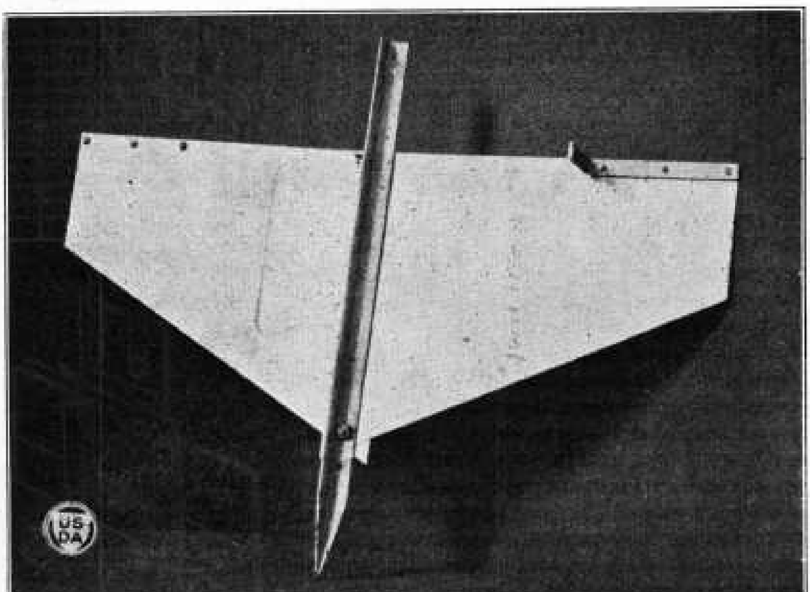

FIG. 11.—Portable metal dam.

number of corrugations. The arrangement of head ditch and distributing basin is shown in Figure 12.

Frequently, as a field becomes well set with alfalfa or other perennial crop, features of the corrugation method of irrigation having the purpose of controlling and regulating streams for each corrugation are discarded and the distribution of water comes to resemble that of the ordinary flooding method. Continuous care should be taken,

however, to see that the proper streams are used to economize in the use of water as well as to minimize the early danger of washing the field.

The outlet from the head ditch to a distributing basin is usually a redwood box about 3 feet long and from 4 to 8 inches square. A shingle over the outer end or a slide or pivoted gate usually serves to close, or partly close, the opening. At the discharge end of the outlet box and against the inside of the outer bank of the distributing basin a wide board should be set to prevent washing away the bank. These outlet boxes are illustrated in Figures 12 and 13.

The flow of water from the head ditch to distributing basins may be controlled by regulation of the water level in the head ditch, which is accomplished by means of checks. These structures may be made of

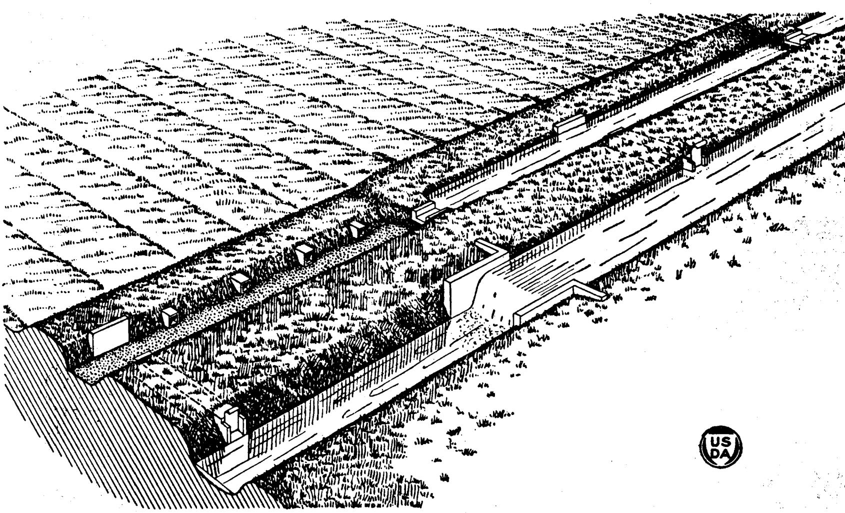

FIG. 12.—Arrangement of head ditch and distributing basin for corrugation method.

wood or concrete (Fig. 14) or may be merely canvas dams. Besides providing a means for proper adjustment of the flow to each distributing basin, the check automatically takes care of any increased flow which might occur in the head ditch by allowing excess water to pass over its crest.

At intervals, depending upon the spacing of corrugations, provision is made to allow small streams of water to feed from distributing basins to corrugations. These streams vary from one-fifth to 1 miner's inch, depending upon the size which may be used safely without washing or flooding the soil. Where the soil is heavy enough to withstand washing at these outlets, distribution is accomplished merely by grooving the lower bank deep enough to permit passage of the proper stream of water. Sometimes pieces of burlap are embedded in the grooves, and where very loose soil and steep slopes have to be dealt with coarse manure or fine straw is mixed with the earth, forming the lower bank of the distributing basin. After being thoroughly puddled and packed, this makes a firm bank that will not

wash readily. The irrigator usually makes the groove by first denting the bank with his shoe, later shaping it with the blade of a hoe.

One of the chief faults of such a system is the tendency of débris to choke the flow of water through the grooves after the streams

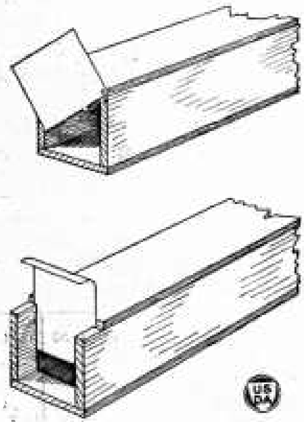

Fig. 13.—Outlet boxes used to connect distributing basins and head ditches.

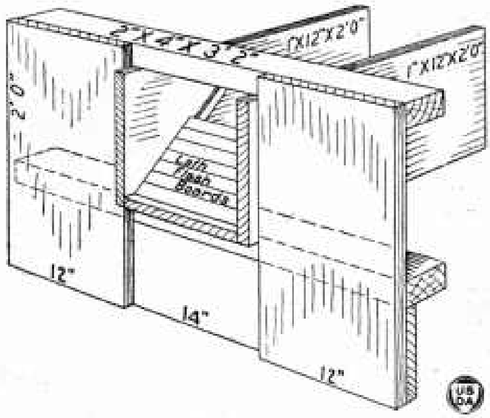

Fig. 14.—Wooden check used to regulate flow of water in head ditch.

have been regulated. Usually the irrigator will regulate a stream during the day and at evening will consider it safe to leave until the next morning. If a storm occurs, the irrigation ditches are filled with trash and, if nothing worse happens, the distribution system is

Fig. 15.—Four corrugations supplied from single outlet.

likely to become clogged, causing water to back up in the distributing basins until it breaks through the bank and flows down the field in a stream of sufficient size to cause more or less damage.

To overcome this danger, a small wooden overflow box (Fig. 12) may be placed in the banks which divide distributing basins so as to

allow water to flow from one basin to another after the high-water mark is reached, and finally, if necessary, pass out of the end basin into a waste ditch. Barring accidents due to other causes, such as gopher holes, this will usually eliminate the danger of washing a field, but it does not prevent the waste of water nor the extra labor of readjusting the irrigating streams. Outlets from distributing basins should be, and usually are, made opposite each corrugation. The practice of supplying two or more corrugations from a single outlet, as illustrated in Figure 15, will mean extra work in regulating streams

FIG. 16.—Irrigator regulating streams in several corrugations.

and will add to the danger of washing out the lower bank unless outlets are better protected than in the system shown. Figure 16 shows an irrigator regulating streams of water for a number of corrugations, an outlet being provided for each stream of water. This system of distributing water to corrugations is very generally used, is inexpensive, and gives satisfactory results when properly attended to.

Another arrangement for releasing small streams of water is made by embedding wooden spouts at the same level in the lower bank of the distributing basin so that any water entering the basin is divided automatically. These spouts sometimes are made by nailing four laths together; if a smaller opening is required, it is formed by nailing together two strips in each of which a semicircular groove one-half inch in diameter has been cut; or, if a still smaller outlet is wanted, a lath and one of the strips with the half-inch semicircular groove may be nailed together, thus forming an opening half as large as the round one. These spouts are made in lengths of from 2½ to 3 feet. Wooden spouts are much used, especially when ditches are new and fields have been planted for the first time. Their use eliminates most of the annoyance to the irrigator of having floating débris clog outlets, as may happen when grooves are used, and removes the danger of bank erosion, which is always more or less possible where water is allowed to flow over the bank through an earthen channel. On the other hand, this system, as it is usually installed, does not allow a wide variation in the size of the stream used in the corrugations, which is a serious defect in the watering of such crops as alfalfa and clover, where a fairly large stream is required as the crop matures. If large enough spouts are used to water these crops in the first place

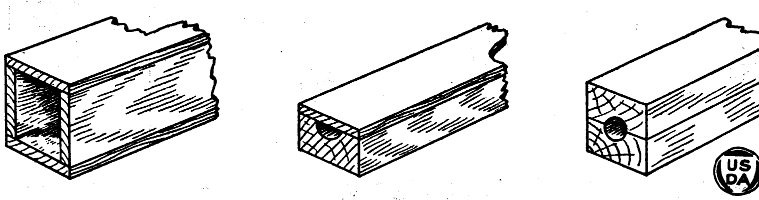

FIG. 17.—Spouts used to release small streams from distributing basins.

it will not be necessary to abandon them later. These spouts decay rapidly and consequently need to be replaced frequently. Spouts dipped in hot creosote before being used will last much longer than those not so treated. Figure 17 illustrates the three types of spouts.

Short pieces of rubber hose are sometimes used to siphon the water over the banks of distributing basins, but this method is probably less practical than those already mentioned.

Wooden or concrete troughs, known as head flumes, with small holes bored through sides or bottom or with their sides notched at the proper intervals to discharge water into corrugations, take the place of the head ditch and distributing basins in some systems. These troughs are made either square or V-shaped in cross section. They must be set close to the ground to prevent excessive erosion underneath. A metal slide, or piece of wood or metal pivoted at one end, serves to open and close the outlet. This arrangement is not used so generally as are the first two mentioned, probably on account of its cost of construction and upkeep; however, it permits of proper adjustment and control of irrigation streams and may be said to represent the best practice where the corrugation method is used. A head flume is shown in Figure 18.

CORRUGATIONS.

Corrugations are essentially small furrows spaced from 16 to 48 inches apart depending on the soil type. When carrying the proper stream of water, they are supposed to irrigate the soil thoroughly, principally by a capillary movement of the moisture. Theoretically the stream used in the corrugations is just enough to supply water for uniform absorption on all sides of the corrugation and throughout its length to a depth not greater than the lowest plant rootlets without any waste at the lower end. The length of corrugations and the distance between them should be such as to accomplish this result. Usually the best practice to follow in making corrugations is to have them neither deeper nor wider than is necessary safely to confine the stream. Shallow furrows are most effectual in spreading moisture horizontally at the ground surface. In the

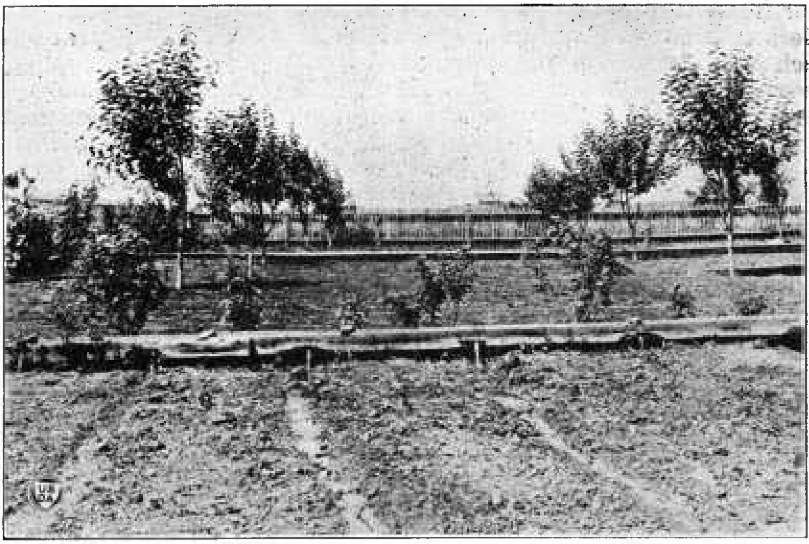

FIG. 18.—Release of water from flume through holes in sides.

irrigation of trees and deep-rooted crops, such as alfalfa, the farmer not infrequently uses deep corrugations with the idea of wetting the subsurface rather than the surface soils, but allows the water to run until moisture shows on the surface. This usually will require a much longer time of application than should be necessary to properly irrigate the crop and will result in a waste of water through deep percolation. Under ordinary conditions corrugations 4 inches deep and 5 or 6 inches wide will be most satisfactory.

The proper distance between corrugations for a particular soil is double the horizontal distance through which moisture will move away from the water line during the time required for the downward moving moisture to reach the maximum depth of plant rootlets. For example, the feeding rootlets of an alfalfa plant extend an average depth of 6 feet into the ground. If the vertical movement of moisture downward is six times as rapid as the horizontal movement, then

soil will be moistened for a distance of 1 foot on each side of a corrugation during the time required for wetting the soil to the proper depth. In this case corrugations should be spaced at intervals of 2 feet. Lava ash soils have almost the characteristics of blotting paper, so rapid is the horizontal movement of moisture and so far does the movement extend. In very heavy soils this horizontal seepage is so slow as to render the use of corrugations ineffective as a means of irrigation. In sandy soil the downward movement of moisture is so much greater than the horizontal movement that the loss of water through deep percolation prohibits this method. The presence of hardpan or some other stratum which will halt the downward movement of water is a favorable condition for widely-spaced corrugations. In general practice the interval between corrugations varies from 16 inches to 3 or 4 feet with the most usual spacing about 20 inches.

In determining the spacing, the irrigator often allows labor and expense to have greater weight than the requirements of the soil. The result is that wide intervals between furrows and slow rates of irrigation are used with consequent overirrigation and a probable development of need for drainage. The simple experiment of running water for different lengths of time through separate corrugations and then excavating a trench across them, exposing the area of dampened soil, will aid the irrigator in determining the proper spacing of corrugations and the length of time that water should be allowed to remain in them for any given soil condition. Since the watering, cultivation, and growth of crops very frequently bring about a change in the physical properties of a soil and subsoil, it is advisable to redetermine the proper spacing of corrugations and the proper rate of irrigation after land has been farmed for five or six years.

The length of corrugations varies from 150 to 1,200 feet, but more often they are from 300 to 600 feet. Generally the longer the corrugation, the more inefficient it is in uniformly distributing irrigation water throughout its length, and consequently it should always be as short as practicable. Under ordinary conditions 300 to 400 feet represents good practice, but shorter corrugations are needed for either very steep or comparatively level lands and it may be advantageous to use longer furrows for soil which absorbs water slowly. On very steep slopes an exceedingly small stream is used in order to reduce soil erosion to the minimum and this stream will not travel very far before being absorbed. Under such conditions the length of corrugations is limited to 200 feet or less. Likewise for comparatively level land fields must be short to confine streams to the small furrows and water the land in a reasonable time.

Slopes giving the least difficulty in the operation of the corrugation method are from 1 to 2 feet per 100 feet, but slopes as great as 15 or 20 feet per 100 feet may be irrigated properly by this method. In fact the greatest advantage of the corrugation method is its adaptability to steep, rough land. For comparatively flat land some method of flooding is much to be preferred, but whatever the grade, it is advisable to run the water in the direction of maximum slope, since any appreciable side slope is likely to cause the breaking over of one stream to the next. A field may be terraced to take up the side slope and so provide a more moderate grade, but the expense

of terracing, the waste of land, the difficulty of keeping the steep slopes between terraces free from weeds, and the added difficulty of harvesting crops make the use of the original slope preferable.

MAKING THE CORRUGATIONS.

Land is corrugated usually just after the seeding of a crop, a horse-drawn implement capable of making from two to four furrows at one time being used. The steel corrugator (Fig. 19) is a manufactured implement and is particularly useful for recorrugating old alfalfa fields, because it is equipped with a vertical knife and a shoe on the runner which cuts through sod better than the ordinary corrugator. The homemade implement shown in Figure 20 has the advantage that it is not easily clogged with trash, the front portion of the runner

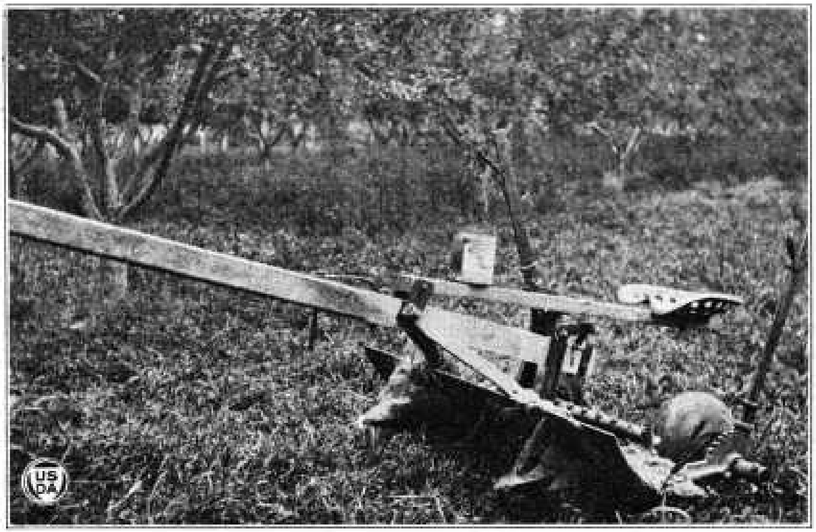

FIG. 19.—Steel corrugator.

pushing aside all material likely to catch on the cutting shoe. Several kinds of corrugators are used, but it will be found that those of the sled type (Figs. 19, 20, and 21) give better results than those mounted on wheels or rollers (Figs. 22 and 23).

The corrugation must be kept open if it is expected to spread water uniformly over a field; if it becomes clogged or damaged so that it will no longer confine the irrigating stream within its banks, the process of irrigation becomes slower and less certain. Such deterioration is caused principally by the use of implements for crop harvesting and the best practice is to recorrugate following each harvest. In the case of pastured fields seeded to grasses, corrugations need cleaning out less often than when wagons and other machinery are drawn over them, but they should not be neglected entirely. Figures 24 and 25 show pastures in which the corrugations have deteriorated.

One man with the proper corrugating implement drawn by four horses can corrugate about 12 acres of land a day.

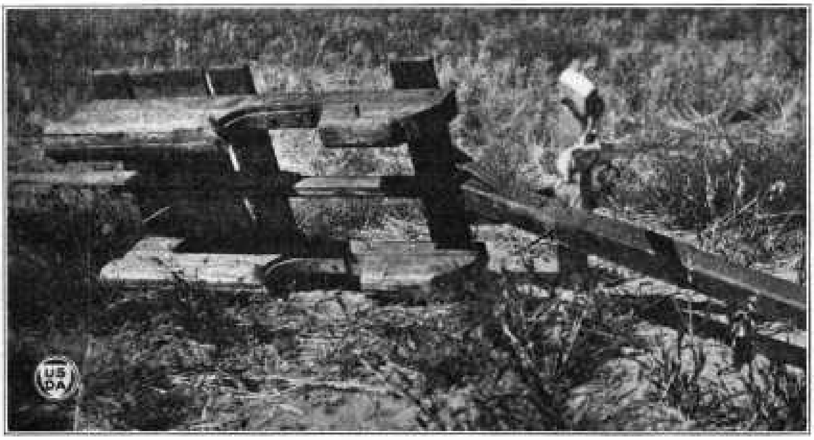

FIG. 20.—Type ofhomemade wooden corrugator.

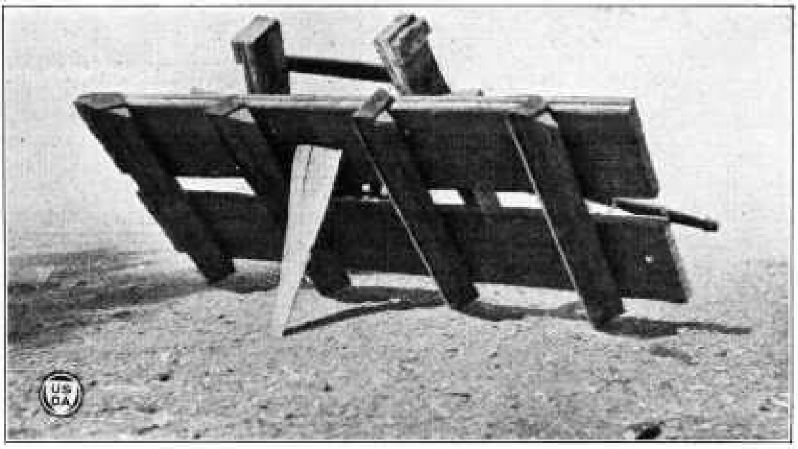

FIG. 21.—Another type of homemade corrugator.

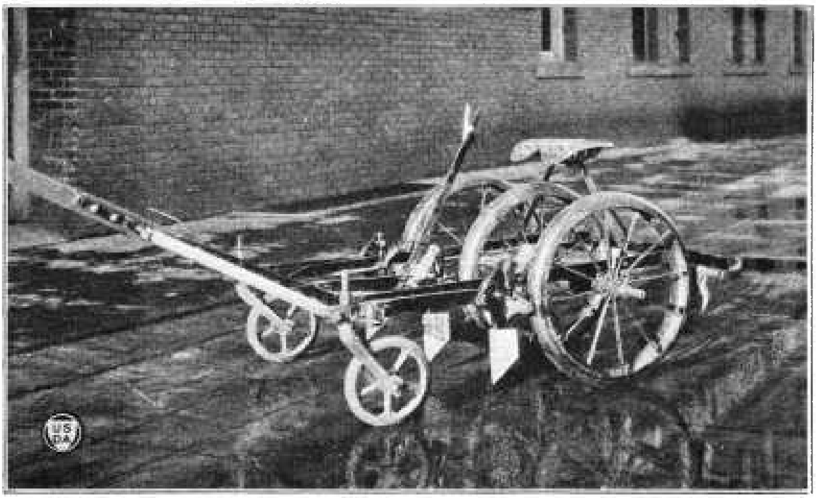

Fig. 22.—Wheel-mounted corrugator.

Fig. 23.—Roller corrugator.

FIG. 24.—Pasture irrigated by the corrugation method. Corrugations slightly deteriorated.

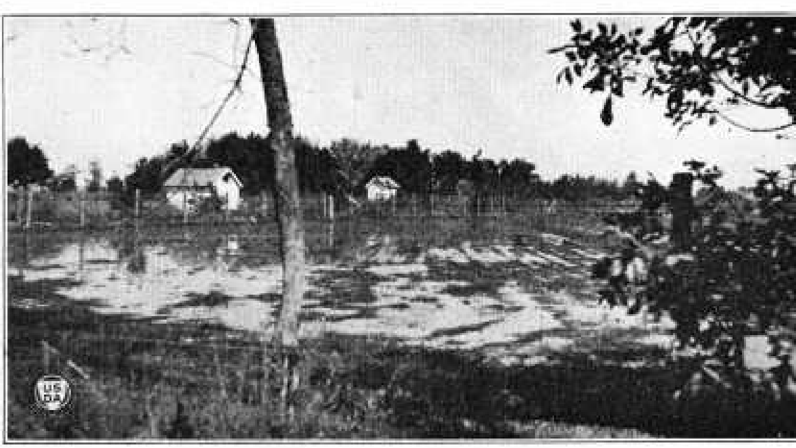

FIG. 25.—Pasture irrigated by corrugations in advanced stage of deterioration.

WASTEWAYS.

Theoretically there should be no surface waste of water where the corrugation method of irrigation is used. As practiced, however, it is most difficult to prevent such waste, and some provision should be always made to use or carry off the excess water. Many fields are so divided as to make possible the collection and reuse of waste water in a series of head ditches located one below the other. In this case the number of corrugations watered should be reduced each time to suit the available head of water. Sometimes the lowest lying field may be converted into a pasture which may be flooded with waste water. Occasionally it is possible to take advantage of a change of grade to slow the irrigation stream at the lower end of the field and thus force more water into the soil and waste less at the end of corrugations.

USE OF WATER IN THE CORRUGATION METHOD.

The adoption of the corrugation method has usually been due to the desire of irrigators to produce maximum crops with the least labor and inconvenience. Considering only the judicious use of water, the method usually could be improved upon. It is impossible to recommend a proper application of this method of irrigation which would suit all conditions, but it is quite within the power of each irrigator to determine for himself the best way to irrigate his land by the simple experiment of using streams of water of different sizes for different lengths of time and then either digging down with a shovel or using a soil auger to ascertain the effect of the irrigation in moistening the soil.

The 24-hour plan is probably the most generally adopted application of the corrugation method. It relieves the irrigator of the somewhat difficult task of regulating and attending to a large number of small streams at night. According to this plan, water is turned into a new set of corrugations in the forenoon and the various streams are adjusted during the day so that they do not erode the soil, overflow the corrugations, or otherwise threaten damage to crop or field. So set, the system is considered safe to be left during the night without further attention. The streams used in the separate corrugations will vary from one-fifth to one miner's inch, the smaller amount being used on newly planted fields or where slopes are steep. The usual regulation of these streams results in considerable run-off at the ends of corrugations, and wasteways or drainage ditches are necessary to carry off the excess water.

This practice is modified in some localities by changing the time during which water is allowed to flow in one set of corrugations. Infrequently the time is reduced to 6 or 12 hours, but more often continuous application for 36, 48, 60, and 72 hour periods is practiced.

Under extraordinary conditions of soil and subsoil this slow rate of irrigation might not result in the use of an excessive amount of water, and if there is no waste, there is no reason why the irrigator should not save himself from the arduous task of night irrigation, but results do not justify this practice generally. The allotment under continuous-flow distribution systems varies from one-half to 1 miner's inch for each acre of land irrigated. It is very doubtful

if so small a quantity of water as one-half miner's inch per acre ever is actually used, and it is known that the maximum apportionment often is exceeded. The allowance of 1 miner's inch per acre for a season of 150 days amounts to the acreage use of water nearly 6 feet deep on the land, and since a portion of a farm is usually devoted to a part-season crop, the acreage irrigated throughout the entire season may actually receive more than the depth of water indicated by the acre allotment. The depth of water actually applied in the corrugation method will usually fall between 4 and 10 feet. Under general agricultural conditions throughout the Northwestern States the depth of water which should be applied to meet plant requirements is much less than this.

UTILITY OF THE CORRUGATION METHOD.

The corrugation method should not be classed with the regular furrow or the border methods so far as general desirability in effecting the application of water to crops is concerned. However, there are conditions which justify its adoption and make it a commendable method of irrigation. It offers a way to irrigate uncultivated crops with streams which would ordinarily be too small for practical use. The continuous-flow system of delivery, wasteful of water and time as it is, has become established throughout the Northwestern States, and its conversion into the more desirable rotation plan, which adapts the irrigation head to conditions of soil, crop, and grade will be a slow process if accomplished at all. Thus in the Northwest there is many a small farm where the irrigator must use, as best he may, a stream varying from 10 to 20 miner's inches of water, and the corrugation method offers the most satisfactory way of applying these small streams of water to crops.

Probably the greatest advantage of the corrugation method is its adaptability to watering very steep slopes. Such land might also be terraced, so providing a grade which would permit the practice of flooding, but as stated before this is not desirable and is often impossible because of the limited depth of good soil. The maximum slope which might safely be flooded during all crop stages is 1 foot in a horizontal distance of 100 feet, and where an old stand of heavy alfalfa or similar growth is present this slope might be two or three times as great, depending somewhat upon the soil. The corrugation method, on the other hand, may be used with a minimum preparation of the land where the fall is as great as 15 or 20 feet in a horizontal distance of 100 feet. A good rule to follow is to use the border method instead of the corrugation method wherever possible. In many instances the latter may be employed where the land is too steep for the use of the border method on freshly cultivated land and later may be converted into the border method, thus ultimately making use of a more economical method of irrigation. The corrugation method, though not the best way to irrigate flat land, may be used to advantage in connection with the border method in the watering of such land with small heads of water. The corrugations in this case serve the dual purpose of keeping the water spread out over the area between borders and leading it along the lands. In the event that the two methods are to be utilized, fields should be pre-

pared for border irrigation [3] before a crop is planted. This adaptability of the corrugation method to steep slopes has resulted in the reclamation of some of the most valuable land in the Northwest and besides has been a factor in eliminating unsightly and undesirable waste land within an irrigation project.

The minimum expense and work attached to the preparation of land and the installation of the corrugation method has proved to be of great assistance to the new settler of the Northwest in that it has allowed him to make the business of reclaiming land pay from the very start. The expense and delay usually necessary for leveling and otherwise preparing land for irrigation is largely eliminated. Clearing away the brush and preparing of a seed bed is usually all the attention new land receives before a crop is planted. Later when the expense may be met easier, undoubtedly it would be advantageous to do some leveling, but as far as general practice goes only a minimum of such work is ever done.

This method of irrigation, although generally resulting in the use of far too much water, permits of a better control of soil moisture at critical times than do any of the methods involving the flooding of the entire ground surface. If the flooding method is used prior to seeding, sufficient moisture must be supplied to germinate the seed and carry the crop to a stage where it will not be injured by the crusting of the ground surface following the next flooding. Failure to meet this requirement is sometimes unavoidable and the result is a loss to the farmer. Not so with the corrugation method. No difficulty need be encountered so far as deficiency of soil moisture is concerned, since water may be applied at any time through corrugations without the disastrous result caused by flooding a newly planted or very young crop, provided water is not kept in the corrugations too long, since in that event the crop will turn yellow and die. Under suitable conditions as to topography and delivery of water, it would seem well to combine this advantage of the corrugation method with the greater economy of the border method. Such a change in method of irrigation would require the special preparation of fields for the border method before a crop is planted.

LIMITATION ON ADAPTABILITY OF CORRUGATION METHOD.

Except under conditions already described where the adoption of the corrugation method is necessary or highly advisable, its use is not warranted, since it generally leads to a practice wasteful of water, time, and labor.

It is wasteful of water because the slow rate of irrigation usually results in moistening the soil deeper than is necessary to meet plant requirements. Sometimes it has been found necessary to abandon the corrugation method in favor of some approved method of flooding the ground surface, because the waste of water proved prohibitive. The slow rate of irrigation, the primary cause of water waste with the corrugation method, is not necessary where crops are flooded because under the latter method the entire ground surface receives moisture through direct contact with the irrigating stream and consequently

[3] Farmer's Bulletin No. 1243. The Border Method of Irrigation, United States Department of Agriculture.

irrigation may be very rapid with consequent shallow application and negligible loss of water.

Where the corrugation method is used, irrigation is a continuous process on each farm throughout the growing season, and the irrigator is never properly relieved of the responsibility of attending to it. Where larger heads of water are used and much more rapid irrigation is practiced, the task is of enough importance to require constant attention, and when finished, as it soon must be for the average farm, water has not been wasted through enforced partial attention, and the irrigator is free to do other work.

The wear and tear on farm machinery and the strain on men and animals in harvesting crops on a corrugated field is another objectionable feature of this method of irrigation. The lack of any systematic method of irrigation on a large number of farms usually may be traced to this objection.

The advantage in the use of the corrugation method for the sprouting of seeds and the furnishing of necessary moisture to young and tender plants, or the necessity of its use for starting crops on steep lands should not justify its use indefinitely when conditions will finally permit the use of an approved method of flooding the ground surface.

The corrugation method is not adapted to washing alkali from the soil, the desired action of carrying the bulk of the salts downward with the water to safe depths below the ground surface being reversed. Horizontal seepage from both sides of the furrows and evaporation on the ridges will result in concentrating more alkali between furrows than is washed downward under the limited area over which water flows. Cultivation of the ground surface might retard this action, but much of the harm is accomplished before the soil is sufficiently dry to work and if the crop is planted the ground surface should not be disturbed. Some method of flooding, not necessarily the border method, should be used to wash down alkali.

Long corrugations and a practice of allowing water to flow for long periods on the same land should be avoided as promoting an extravagant use of water which can be of no extra benefit to crops, but may eventually waterlog the land. The long corrugation also results in uneven distribution of moisture over a field, the upper portion receiving more water than the lower end.

To permit corrugations to clog with sediment and trash until the method has reverted into that of wild flooding is very bad practice. The principle of the corrugation method has faults, but it has advantages that justify its use under conditions described in this bulletin, which is more than may be said of the practice of irrigating by wild flooding with small heads of water.

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